THE INSTITUTE OF PHYSICS
47 BELGRAVE SQUARE, LONDON, S.W.1.

BULLETIN

No. 60 DECEMBER, 1954

CONTENTS

	Page
Summary of a Discussion on the Education of Physicists	217
Notices to Members	223
The British Ceramic Research Association ... By A. Dinsdale	224
Index to Volume 5	237
Appointments Vacant	ii

The Bulletin is not intended for general circulation : your copy should not therefore be passed to a library.

APPOINTMENTS VACANT

The inclusion of particulars of a vacancy must not be taken to imply that the Institute necessarily approves of the terms offered or that might be offered. Candidates should satisfy themselves that these are satisfactory, and they may always refer to the Institute for advice.

Northern Polytechnic, Holloway, London, N.7.

The Governing Body invite immediate applications for appointment as **senior lecturer in physics** for post-graduate work and courses leading to the B.Sc. special degree. Opportunities are available for research. Salary scale :—Men : £1,065 × £25 × £1,215 ; Women : £852 × £20 × £972, plus London Allowance. Form of application, together with full particulars, will be forwarded on receipt of a stamped, addressed foolscap envelope.

R. H. Currell, A.S.A.A.,
Clerk.

Electrical engineers. A well-known industrial organization has vacancies for electrical engineers. First class men, able and willing to shoulder responsibility are sought and there are excellent opportunities for advancement. Vacancies exist for men with experience in either power distribution or instrumentation. For the latter type of vacancy applications from physicists will be welcomed. Starting salaries in the range £600–£900 p.a. depending upon qualifications and experience. Post graduate training leading to professional qualifications can be arranged and normal salaries will be paid during such training. Candidates should hold an honours degree.

Write, giving full details of age, qualifications and experience quoting Ref. U.8 to Box A.V.71, The Institute of Physics, 47 Belgrave Square, London, S.W.1.

Large British Oil Company has vacancies for **geophysicists** on its exploration staff. Candidates should have an honours degree in physics with subsidiary mathematics and/or geology, but candidates with a general degree will be considered. The work involves delineation of underground rock structure by seismic, gravitational and magnetic techniques and offers considerable scope for men with initiative who are prepared to travel and to work abroad. Normal leave is four months after two years' foreign service.

When conditions permit, facilities are afforded for married men to have their families with them on foreign tours.

Basic salary is commensurate with age and experience, commencing at £820 for young, inexperienced graduates. Appropriate allowances are paid whilst on foreign service. Generous pension scheme.

Applications quoting F.107, should be addressed to Box 1223, c/o 191 Gresham House, E.C.2.

Research Laboratories, British Electricity Authority, Leatherhead, require **two general assistant engineers.**

Candidates should have a university degree or equivalent qualifications in electrical engineering or in physics. Duties include research on electrostatic precipitation and allied problems at Leatherhead and Croydon laboratories. Salary N.J.B. Grade 5, £531–£732 per annum.

Applications stating age, qualifications, experience and present position and salary should be forwarded to D. Moffat, Director of Establishments, Winsley Street, London, W.1, by December 10, 1954. Quote reference BIP/541.

British Rayon Research Association. Physicist required, to continue research on the drying of yarn packages. A good honours degree is desirable, and some research experience, not necessarily in textiles, will be an advantage. A knowledge of electronics will also be useful. Applications, with full details and names of two referees, should be addressed to the Secretary, British Rayon Research Association, Heald Green Laboratories, Wythenshawe, Manchester.

Physicist required for new research laboratories to supervise investigations into the properties of non-metallic materials used in the packing of delicate instruments subject to vibrational and shock loading conditions ; a knowledge of metallurgy and corrosion problems advantageous. A degree standard in appropriate subjects and some practical research experience are required. The appointment is permanent and offers excellent prospects, with a starting salary of £800–£1200 depending upon qualifications and experience. Apply in writing to **E.P.S. Limited, Research and Development Establishment, Sittingbourne, Kent.**

Messrs. Barr & Stroud Ltd., Anniesland, Glasgow, require the services of a young man, preferably with a university degree in Engineering or Physics and with some industrial experience.

Applicants must have a sound technical and scientific education such as would be required to carry out research and development work associated with scientific instruments of a wide variety.

The work is interesting and offers scope to a man of outstanding ability.

Applications should contain full particulars including age, nationality, school and college education, industrial experience, also salary required. Replies should be addressed to the Secretary.

Physicist or **mathematician** with good university degree and with knowledge of optics to undertake design, computations and testing of a wide variety of optical systems. The post offers scope for a man of original ideas and initiative. Applications stating age, qualifications and experience to The Secretary, Barr and Stroud Limited, Anniesland, Glasgow, W.3.

An **engineer** or **physicist** is required for development work in methods of non-destructive testing and for the design, construction, and maintenance of instruments for use in research. Preference will be given to candidates with good experience in electronics. The post carries superannuation. Application should be made to :—The Director, Aluminium Laboratories Limited, Banbury, Oxon.

Physics laboratory. Vacancy exists in laboratory of engineering firm, with scope for original work in all branches of physics, for **graduate** in pure or applied science, preferably with some experience in industrial research.

Applicants must be free from National Service obligations.

Apply to The Secretary, Barr and Stroud Limited, Anniesland, Glasgow, W.3.

(*Continued on page iii*)

THE INSTITUTE OF PHYSICS

No. 60 BULLETIN DECEMBER, 1954

SUMMARY OF A DISCUSSION ON THE EDUCATION OF PHYSICISTS

A meeting of the Yorkshire Branch of the Institute was held at the Technical College, Bradford, on May 6, to discuss the problems involved in the education of Physicists. The Branch Chairman (Professor E. C. Stoner, F.R.S.) was in the Chair. This summary of the opening speeches and the discussion has been prepared by Dr. R. S. Tebble, Honorary Secretary of the Yorkshire Branch.

PROFESSOR STONER, in introducing the subject, said that for the last twenty years or more there had been an increasing need for more scientists, and in particular for more physicists, in industry and in various forms of government service. It was recognized that the future welfare of the country would depend more and more on the extension of scientific knowledge and its technological application. Physics was in a special position, for some background study of physics was necessary for effective work and understanding in most of the other sciences and the technologies. Moreover, that exploration of certain fundamental and inescapable aspects of the world, which is physics, was an adventure of mankind which had a value independent of any narrower " usefulness " it might have ; and it should certainly be introduced in some form and in some degree to all young people.

The problems of how physics might best be taught at various stages and for various purposes were vitally important and were properly under continual discussion ; at the moment they were overshadowed by the pressing problem of how to ensure that physics shall continue to be taught at all at the upper school level. At present, in England and Wales there were each year some ten thousand entrants for G.C.E. Advanced Level examinations in physics. For most of these physics was not subsequently a main field of work or study. The number graduating annually from the universities with physics as a main subject was some six or seven hundred. This was the supply of well-qualified physicists available to meet the requirements of industry, government service, universities, technical colleges and schools. School-teaching ,with its relatively low financial rewards, was attracting fewer and fewer of the better graduates in physics, while at the same time good teaching in physics to a fairly high school level was becoming more and more necessary. The difficulties were sometimes exaggerated, but they could not be overcome by half-hearted palliative

measures. Increasing the supply of physicists would not alone solve the problem. The basic need was a better distribution of the available supply, and this would only be achieved if the financial rewards for different kinds of work, equally essential and equally exacting, were somehow made more nearly comparable.

MR. H. STEELS (*Roundhay School, Leeds*) said that it was essential that a sound foundation in the education of the physicist should be laid in the schools lest the subsequent structure be insecure. In considering the training of the young physicist from 11 to 18 years it was important to get the correct perspective. Approximately 15 per cent of the school populations went each year to a grammar school and from there only about 1 in 5 went on to a university ; of these only a few read physics. Bearing in mind the type of training required to produce a well-educated man and at the same time to prepare pupils for the entrance requirements of the universities and various professional bodies, the schools aimed at a well-balanced and comprehensive curriculum during the first three or four years. As time went on, emphasis in choice of subject changed, more periods being allowed for some subjects while other subjects were shed. The branches of physics chosen to be taught in the period 11–15 or 16 years were much less important than how they were taught. Ideally a sound grounding should be laid by a well-qualified and able schoolmaster, eager to instil the spirit of the subject as well as its factual training and alive to the moral training involved. Physics should be linked up with other subjects in the curriculum, special attention being paid to the writing of good clear English. The young physicist progressed in experimental work from a judicious mixture of sensational demonstration and simple experiment to the carefully carried out experiment requiring skill and accuracy in manipulation. This led to the ultimate ability of working and studying on his own. Original work done only 10–15 years ago was, quite rightly, finding its way into teaching at VIth form level. Thus a physics master teaching VIth forms must be sufficiently well-qualified and have the time available to keep abreast of his subject.

Present conditions prevented the general achievement of this not impossible scheme of training. Large classes greatly increased time taken in marking ; increased strain was caused in the laboratory because of the danger of accident ; the laboratories were in constant use, leaving no opportunity for setting up apparatus beforehand, while repairs and replacements constituted a major problem ; there was no opportunity for individual work before the VIth form. It was also possible to see in some places in the country political influence and local prejudice replacing true education ideals. The shortage of well-qualified teachers was due to several reasons. The profession

needed more differentiation in salary to give prestige to high qualifications and responsibility. Grammar school masters at VIth form level could not be persuaded that technical scales should be so much better than their own. The chances of promotion after the age of 40 were slender and were further limited for the science teacher because he taught science.

The recruiting of teachers of a lower scientific calibre in an attempt to overcome some of these difficulties could only lead to worse conditions. A graduate in science was essential for the teaching of physics at any stage in the grammar school. Better use should be made of first-rate schoolmasters already in the schools to train science graduates to be good schoolmasters. The supply of honours graduates was strictly limited but a few must be found for teaching at VIth form level.

DR. D. L. SMARE (*The Technical College, Bradford*) believed that the education of physicists, as distinct from the teaching of physics, in Technical Colleges, presented a number of difficult problems. That of major importance seemed to him to be the question as to the type of course on which resources should be concentrated. About forty technical institutions, out of approximately 250, were recognized by the Institute as being capable of training physicists : practically all these institutions provided courses leading to Ordinary and Higher National Certificates in Applied Physics. As these courses were on a part-time basis the local demand varied enormously. For full-time students the courses provided hitherto lead to B.Sc.(London), Special or General. Outside the London area few students presented themselves for the Special degree ; in 1951 there were only about 25. Apart from the emergency conditions in the immediate post-war years it seemed very doubtful whether Special degree courses were well adapted to Technical Institutions. The General degree, physics with mathematics, or with mathematics and chemistry, was also unsuitable because of the limited range of the syllabus and the fact that physics was only one subject out of three. Little help seemed to be forthcoming from the proposals, approved by the great majority of the 250 colleges but fortunately in abeyance, that a Royal College of Technology should be set up to grant diplomas or degrees on the basis of courses in Technical Colleges. The chief hope lay in the establishment of a degree course in applied physics or in the Institute's own Graduateship course : while the really promising student should go on to the University, a considerable number of good physicists could be trained in Technical Colleges by taking the Graduateship course.

The achievement of this aim depended upon the willingness of schoolmasters to recognize the value of the Graduateship and to recommend it to suitable candidates.

PROFESSOR J. G. WILSON (*University of Leeds*), said that, although the output of physics graduates had increased greatly since the war, it was at the moment inadequate and reasonable forecasts predicted a persisting demand. The immediate bottleneck was shortage of applicants to university departments from the schools, for the problems associated with increased size of honours schools were with us already, and further moderate expansion would not bring essentially new problems. At schools the limitation was probably already weakness of staff in a significant (and increasing) proportion of schools. This was indicated by the strikingly uneven numbers in which schools, similarly placed, sent forward applicants. The problem of staffing was mainly financial, and efforts to disguise the necessity of substantial salary differences through the teaching profession had been of serious disservice to the nation.

The Chairman's figures showed that, except in the smallest universities and university colleges, the average number of entrants to honours schools of physics must be forty or rather more. The majority of physicists were taught in the larger schools and, since the larger schools included the most sought-after, the proportion of the really promising men taught in them was very high ; imaginative action to exploit the undoubted advantages of the large honours school and to eliminate as far as possible its drawbacks was a central problem of internal organization in university schools of physics if we intended to maintain, let alone expand, the present output of trained physicists.

DR. A. B. D. CASSIE (*Wool Industries Research Association, Leeds*), considered that, even with no defence requirements, the demand from industry for physicists would expand, and the difficulty of obtaining honours graduates in physics for schools was likely to become more acute, unless there were a reorganization rather than revision of school salaries. Failing this, the Universities might have to extend their vocational training of physicists with a 4-year course, possibly beginning at the age of 17. So far as Univeristy education was concerned he favoured honours physics courses even for those who were to become technologists ; the details of technology could always be learnt as and when required, and too much of it might well be a waste of time.

Physics as a part of general education would become increasingly important, particularly for those who entered industry. The tendency everywhere was towards more automatic machines, and even towards the automatic factory. Men who were to run this new type of industry must be much more knowledgeable than those concerned with production by the employment of operatives. Foremen and managers must be able to get the best out of the machines and to be sure that they were using them in an efficient way. It was a change from the man who

knows how to do a job to a man who knows why it is done at all. That, he thought, was rather a big change from the educational point of view. Men were at present instructed at technical schools in how particular jobs had been done in the past, but such training would not be adequate for the automatic factories that were coming along. The mental training required to run such factories was essentially that given by learning how things work—or by physics. In short, National Certificate courses in physics might well form the background training for future technicians, including managers, just as honours physics courses would be required for future technologists.

DISCUSSION

There was a considerable difference of opinion between members from the universities and from the schools as to the general standard reached by pupils taking the Advanced Level examinations in the G.C.E. DR. F. E. HOARE (*Leeds*) and MR. N. TUNSTALL (*Leeds*) held the view that students entering the university from school were ill-prepared and that their factual knowledge was scanty and unreliable. They might be well acquainted with the " frills " but had little understanding of basic elementary principles, as shown by their inability to work out simple examples.

MR. STEELS replied with some vigour, firmly declaring that any candidate having a reasonable pass at the Advanced level had a good factual knowledge of the subject. There were, said MR. STEELS, no " frills " in physics. After further discussion on this point, Professor Stoner suggested that there were wide differences among students and among teachers and that the failings of some university entrants might arise from the reprehensible practice, in certain schools, of abandoning teaching for question-spotting.

DR. R. S. TEBBLE (*Leeds*) pointed out that the universities were not completely blameless in their methods of teaching. The final product of a university physics department was often a man with a first class knowledge of physics who was incapable of expressing himself in even the simplest English. DR. E. L. YATES (*Sheffield*) considered that the university lectue courses needed revision and that the various branches of physics should be synthesized. Uninspired teaching was unlikely to encourage students to enter the profession, and the university teachers should give more consideration to their methods of presentation. MR. THORNDIKE (*Leeds*) suggested that courses in physics should include adequate practical work made as interesting as possible. DR. F. HAPPEY (*Bradford*) welcomed Dr. Smare's suggestions for courses in Technical Colleges and pointed out that there was an important place in industry for physicists in development work. " Average " physicists with a desire to see ideas developed were, he thought, better suited for such work that the more scholastically minded scientist.

MR. J. HOLDEN (*Leeds*) emphasized a point made by Dr. Cassie that just as it is now considered that the training of all scientists and technicians must include a sound basis of mathematical principles, so should it also include a knowledge of physical principles, as well as of those applications with which the student was immediately concerned.

Much of the discussion centred on the problem of the supply of physics teachers in the schools. It was generally agreed that the position was serious and Dr. Yates suggested that the Universities could help considerably by emphasizing the importance of teaching ; there was a tendency to encourage all the best students to pursue research.

DR. M. MCCAIG (*Sheffield*), although welcoming the removal of the conditions formerly attached to the award of grants of teachers in training at a university, felt that before this was done an alternative inducement to teach should have been found. MR. ROSE (*Leeds*) suggested that the problem of the provision of physics teachers was bound up with the methods of teaching students. Students would only be attracted to physics as a career if the subject were taught at school with such ability and enthusiasm as would attract the most able. The arrangements of meetings and course at the universities would assist the schoolmasters in keeping in touch with recent work.

The Chairman suggested that, though a much greater differentiation in teachers' salaries might be desirable, great care was necessary in formulating criteria. It seemed absurd, for example, that the decision as to whether a teacher should be given a small increment now should depend on just where he might be deemed to have been placed in Class II of Honours in an examination held twenty-five years ago. The interchange of views between teachers of physics in schools, technical colleges and universities could be most valuable. Indirect contacts through representatives, were more numerous than individual teachers sometimes realized. Meetings of a wider kind, if not too frequent, could be both enjoyable and useful, and, given assurance of active support, arrangements could be made as for this meeting and in other ways. In stressing the need for more physicists, it should be borne in mind that it might be possible to meet it only by reducing the numbers in other groups, engaged in studies or work of comparable importance. The problem of achieving a reasonable balance was as crucial here as in the distribution of available physicists. Finally, in connection with the education of physicists, the Chairman underlined the importance of the character and outlook of the individual teacher. Professional competence was not enough in the teacher ; it must be accompanied by a wider sense of values, by what can only be called honesty with himself and his pupils and in relation to his subject, and by an unusually large measure of common sense.

NOTICES TO MEMBERS

Payment of Annual Subscriptions

In order to reduce the cost and labour involved in the collection of annual subscriptions it is proposed to modify the system which has been used in past years. Hitherto, all members except those who have completed Banker's Orders have been individually notified at the end of December of the amount of the subscription due for the following year. No such notification will be sent this year. Instead, a form will be included in the January *Bulletin* and members will be invited to use this in forwarding their 1955 subscriptions. They are asked not to send remittances until they have received the January *Bulletin*. This arrangement does not, of course, affect those who already pay by Banker's Order.

Handbook and Regulations

A new edition of the handbook and membership regulations, incorporating the regulations and syllabuses of the Graduateship Examination, has been produced. Copies are available free of charge on request.

Graduateship Examination

Students are reminded that December 31, 1954, is the last date for the receipt of applications to sit the 1955 Graduateship examination. Application forms may be obtained from the Secretary.

A further volume of laboratory and workshop notes.

A third selection of laboratory and workshop notes and cognate articles reprinted from the *Journal of Scientific Instruments* has just been published, with the title, *Laboratory and Workshop Notes, 1950–1952*, by Edward Arnold (Publishers) Ltd., at 30s. net. Once again, through the courtesy of the authors, the royalties from the sale of this volume will be placed to the credit of the Institute's Benevolent Fund.

The new collection is divided into the following sections : Mechanical design ; Laboratory tools, methods and hints ; Optical and thermal devices and techniques and infra-red spectrometry ; Devices for liquids and gases ; Vacuum devices and techniques ; Electrical devices and techniques.

One reviewer referred to a previous volume as " a catalogue of ingenuity " and this might equally be said of this new selection. It was because of the success of the first two volumes that the Board of the Institute decided to publish further volumes from time to time in order to assist laboratory workers and, at the same time, to help its Benevolent Fund.

THE BRITISH CERAMIC RESEARCH ASSOCIATION

By A. DINSDALE, M.Sc., F.Inst.P.
(*Assistant Director*)

I — INTRODUCTION

The ceramic industry is perhaps the outstanding example of an activity of man which has its origins in the early dawn of history, but which also has its own peculiar and vital place in the complex industrialized society of the present time. It is not known with any precision either when or in what manner the essential properties of clay were first noticed. They probably did not become apparent all at the same time, and the story may well have been of a gradual but growing consciousness of the fact that clay was an abundant natural material, that when mixed with enough water to make it plastic it had the capacity to take up and retain a wide variety of imposed shapes, and finally that when heated it changed its nature and became a strong rigid solid with many of the characteristics of natural stone. Certain it is that bricks were being made from clay ten thousand years ago, and that pottery of a high standard was a prominent feature in several of the Eastern civilizations that flourished many centuries before the Christian era.

Many of the arts and crafts of early man, however, have either disappeared from memory or taken an honoured but static place in the museum or the history book. What is remarkable about ceramics is that it has maintained, and indeed increased, its significance in the industrial activity of the modern scene. To such an extent is this true, that it is difficult to imagine what life would be like without it. There would be no cups and saucers on our tables ; no glazed tiles or sanitary ware ; no electrical ceramics, with an almost unimaginable curtailment of the distribution and use of electricity and of the radio industry ; no furnaces for iron and steel, non-ferrous metals and glass ; no retorts for gas-making ; no bricks or roofing tiles for houses. In the future the use of ceramics is likely to increase rather than diminish, and will extend into entirely new fields where it is becoming increasingly obvious that the use of metals is subject to considerable limitation.

Perhaps even more remarkable than this is the way in which the ceramic industry has been able to absorb to its advantage the modern trend towards an increasing application of science and technology to industrial techniques. This assimilation is much easier in the case of industries, such as plastics or radar, which have grown up on a scientific basis, but presents a very different problem in the case of industries based on tradition and inherited skill, going back many hundreds of years. It is the purpose of this article to give a glimpse of the extent to which the ceramic industry in this country has developed

its research on an organized basis, to indicate the main functions of a Research Association in such an industry, and to show one or two examples of problems which may interest the physicist.

II — HISTORY OF THE RESEARCH ASSOCIATION

The present Research Association represents the confluence of a number of streams, some of which have been flowing for a relatively long time. The first attempt at organized research on refractory materials in this country was sponsored by the Institution of Gas Engineers in 1910 ; the British Ceramic Society had been founded in 1900, and both these activities tended to set the stage for ceramic research in Stoke-on-Trent. With the outbreak of the first World War, the Steel industry realized that it was at a disadvantage because of the lack of precise knowledge of the properties of refractory materials, the position being aggravated by the pre-war dependence of the industry on Austrian magnesite for the hearths of its basic steel furnaces. The Faraday Society held a discussion on refractories in 1916, and a month later the Refractory Materials Section of the British Ceramic Society was formed.

By this time the D.S.I.R. had been established and in 1920 the Refractories industry, now attuned to the idea of research, asked for the formation of a Research Association, which took place in 1920. The Institution of Gas Engineers had co-operated with the Research Association from the outset, and in 1929 liaison also began with the National Federation of Iron and Steel Manufacturers (now the British Iron and Steel Federation). The world trade depression of 1932 led to a temporary set-back, but a special meeting with representatives of the Gas, Iron and Steel, Chemical, Pottery and Electrical industries, in addition to the leading manufacturers of refractories, led to a substantial increase in subscription. In 1936 a further meeting was held and the importance of the Research Association's work to the heavy industry of the country was stressed.

With the outbreak of war in 1939, the programme of research had to be adjusted to some extent. Alternative raw materials were examined, methods were developed for the obscuration of kiln glare, and advice was given to many Government Departments, particularly to the Ministry of Supply and the Ministry of Fuel and Power ; for the Ministry of Works, surveys were made of labour requirements and kiln efficiency in the Heavy Clay industry. This work brought the study of the technology of the Heavy Clay industry within the accepted scope of the Association's research.

The first contact between the Pottery industry and co-operative research was made in 1932, when the British Pottery Manufacturers' Federation contributed £500 to the British Refractories Research

Association for work on saggars, the refractory containers used in the firing of pottery. In 1934 the manufacturers of earthenware and tiles formed small research bodies (unattached to the D.S.I.R.). Three years later a comprehensive scheme of research for the whole of the Pottery industry was formulated within the framework of the D.S.I.R., the British Pottery Research Association being formed in 1937. A joint committee of the two Associations was immediately formed to prevent overlapping of their research programme.

The fusion of the British Refractories Research Association and the British Pottery Research Association was recommended by the Industrial Grants Committee of the D.S.I.R. in 1946, and eventually took place in 1948 when the British Ceramic Research Association was formed.

Plans were already in existence for a laboratory more commensurate with the needs of a ceramic research station, and in September 1947 the new building was begun. The new laboratories were officially opened by H.R.H. The Duke of Edinburgh in 1951.

The laboratories are equipped for almost every kind of work from pilot-scale preparation of bodies, to X-Ray and electron microscope techniques ; from portable equipment used for studying the characteristics of plant on the factory, to calculating machines used by the mathematicians and theoretical physicists.

Of great interest to most research workers is the question of publication of their work. In this Research Association most of the work is published in the form of printed research papers circulated confidentially to members in the first instance. After a short period, some of it is released for open publication in suitable journals In appropriate cases open publication is permitted immediately, and members of the staff frequently contribute to the proceedings of learned societies.

The staff of the Association at the present time is about 180, of whom about 60 are graduates or of equivalent status. The majority of these are physicists and chemists, but there are also engineers, geologists, mathematicians, fuel technologists.

III — THE ROLE OF THE RESEARCH ASSOCIATION

The function which a Research Association has to fulfil in the industry which it serves is not easy to define, and is the subject of much misconception. Three main tasks may be mentioned here, and if they are given due weight and significance they will normally determine the pattern of the research which is carried out.

In the first place, the Research Association has to direct its attention to problems which are of major economic significance to the industry as a whole. These problems are very varaiable in nature.

They may be associated with faults which arise in manufacture, resulting in considerable monetary loss. They may be concerned with the efficient use of materials, fuel, labour or space. They may have to do with the durability, performance in use, or appearance of the finished product. But they have one thing in common, namely, that their solution will yield a tangible economic return.

No-one can be associated for long with this kind of objective research without becoming acutely aware that the situation is not as simple as it appeared to be at first sight. All too frequently the solution of these problems is held up, or rendered impossible, because certain fundamental knowledge is not available. It is, therefore, vitally necessary, in the second place, that the Research Association should carry on work of a much more long-term nature. This kind of work has been well described as " objective fundamental " ; that is to say it is of a sound scientific quality, and has all the special flavour of thoughtful and precise investigation, but is conceived within the framework of a known requirement. The Research Association is ideally equipped to prosecute this kind of work. It can afford to set aside the staff and facilities required, but at the same time has the necessary contact with industry to ensure that the research, while unhampered by the day-to-day pressure of industrial requirements, is nevertheless relevant to the industry's needs.

Thirdly there is another function which is not generally appreciated. Most industries develop in their technological conceptions, as they modernize their processes. In some cases, these changes can be of a very deep-rooted kind and are not always accompanied by an adequate understanding of their significance. It is at this point that the Research Association can work with the industry to obtain the technical data required for the best kind of progress to be made. This may involve accurate observation and interpretation of data, rather than research as it is more commonly understood, but it is of vital importance. Many examples could be quoted in the ceramic industry, the most obvious being in the field of firing.

During the last twenty years or so, the pottery industry has been changing its methods from the intermittent bottle-shaped kiln to the modern continuous tunnel kiln. The Research Association has developed methods of testing the efficiency of these kilns, and of analyzing their advantages and disadvantages. It has issued detailed reports on many different types of kilns, using various kinds of fuels, and has built up a picture of the essential differences between the old practice and the new. This enables the manufacturer to see more clearly the relative significance of features of design ; the importance of insulation ; the distribution of temperature ; the economic factors ;

the changes in labour requirements ; and so on. Hand in hand with this change has gone a general speeding up of other processes, such as making and drying. In these too, tests of a wide variety of types of equipment have enabled the essential requirements to be more clearly understood. Further, the changes in these processes require a closer control of the properties of raw materials, and the Research Association can give great service here by developing systems of control, instruments and quicker and better methods of testing.

The real place of the Research Association *vis-à-vis* the industry is therefore neither in front nor behind in any absolute sense. It should lead in its fundamental work, but should also be intimately linked with current practice in some of its other activities, and in this latter function it can often accumulate such a fund of technological experience and knowledge as to become a bulwark against uncertainty.

IV — APPLICATION OF PHYSICS TO CERAMICS

Much of the foregoing has been necessarily concerned with generalities, but it would probably help the reader to understand more clearly the kind of application of physics to ceramics which is possible, by filling in the picture with more detail. In what follows a more detailed account is given of a few of the problems at present being tackled by the Research Association, chosen to illustrate some of the points which have already been made.

(*a*) *Thermal Properties.*

When a refractory brick forming part of the structure of a furnace receives heat from the furnace, it will retain some of it and transmit the remainder. If the furnace is intermittent in nature, the heat stored up in the brick will be lost on cooling. Whether the furnace is intermittent or continuous, the heat transmitted will be lost to the surroundings. Both these features are of great importance in furnace design, in efficient operation and the maintenance of high temperatures and in fuel economy. It is immediately clear that a profitable research activity is a study of the thermal properties of refractories, and especially of their specific heat and thermal conductivity.

In the case of specific heat, it is interesting to note how certain well-known theoretical relationships can be applied. According to the theory of Debye, the specific heat of solid materials can be related to the atomic weight and the ratio of the temperature to a characteristic temperature, which is generally called the Debye temperature. For a particular value of this ratio, the atomic heat should be constant. If the main atomic weights for all the various types of atoms making up a structure are used for the calculation, the atomic heats of many ceramic oxides are found to fall on the same curve. It is interesting to note that silica, alumina and magnesia, which are to be found in

great abundance in most refractory materials, have almost the same average atomic weights. It might be expected, therefore, that the specific heat of refractory materials wolud be reasonably constant. This is found to be so in practice and the variations of specific heat with composition and with method of manufacture are not very great.

When we turn to the thermal conductivity, which determines the amount of heat which flows through a ceramic material, we find quite a different state of affairs. The thermal conductivity depends both upon the conductivity of the solid material present and on the texture of the material in bulk, particularly with reference to the amount and size of the pores. Measurement of thermal conductivity represents a very important example of the application of the techniques of physics to an industrial problem. The precautions which have to be taken in this kind of work are fairly well known, but the extension of measurements to higher and higher temperatures greatly increases the difficulties involved. It is becoming increasingly important to have accurate data at high temperatures, as the working temperature of furnaces tends to increase. Particular attention has been paid in the Research Association to the development of apparatus giving more accurate results at higher temperatures than has hitherto been possible. It is now possible to make measurements with a hot-face temperature up to 1,400°C. The main features of the apparatus are shown in Fig. 1. The essence of the measurement is that heat is caused to flow

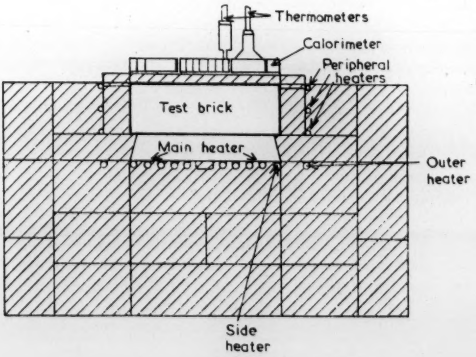

Fig. 1 — *Apparatus for measuring thermal conductivity of refractory materials.*

in a linear manner through the test brick, and that the amount of heat flowing is measured by means of a water flow calorimeter. In order to ensure linear flow it is necessary to use the usual guard ring technique and it has also been found desirable to supplement this by the use of heaters at the side of the specimen. It should also be noted that if the calorimeter is placed directly on the specimen, the cooler face cannot be very much hotter than the water in the calorimeter and thus it does not resemble the conditions in modern furnaces. The temperature of the unheated face of the slab can be brought up to a higher temperature by interposing a sheet of thermal insulating material between it and the calorimeter assembly, but this adds to the difficulty of maintaining linear heat flow. Satisfactory results have, however, been obtained by the judicious use of side heaters to control the direction of flow.

Thermal conductivity is a difficult property to measure and one of the most striking things about published data is a marked lack of concordance between the results. In an attempt to see whether recent improvements in experimental method had reduced this divergency, a co-operative test was recently carried out using the British Ceramic Research Association's apparatus on the one hand, and an apparatus based on the American standard method on the other. It was found that the maximum discrepancy between the two was less than 5 per cent, which compares very well with variations of up to 25 per cent which have been found amongst previously quoted results. The importance of the collection of more and more accurate data at still higher temperatures cannot be over-emphasized. It is one of the ways in which the physicist can help the furnace designer and the combustion engineer to do his job with more precision.

(*b*) *Rheology.*

The products of the Pottery Industry are fabricated in a number of different ways. They may be pressed from dust, shaped from plastic clay or cast from slip. In the latter process, the clay or body is made up in the form of a fluid suspension in water, poured in suitably shaped Plaster of Paris moulds, and allowed a certain period of time for the cast to form on the surface of the plaster. The surplus slip is then poured off, and when the cast dries, it separates from the mould and can be removed. It is immediately obvious that two factors influence the rate at which the slip will cast. One involves the transfer of water from the slip into the porous mould, and the other is the facility with which the slip itself develops a rigid structure. The properties of the slip are of paramount importance in the successful operation of this process. It is desirable that the slip should be as fluid as possible, while containing the maximum amount of solid matter in relation to the water present ; that is to say, it should have the maximum fluidity

consistent with high density. It should also possess a certain amount of thixotropy, since this will assist it in attaining rigidity during setting. A detailed survey of the behaviour of casting slips on factories, using statistical methods of assessing significance, showed that fluidity and thixotropy were the most important factors to be controlled in an industrial system in order to maintain constancy of behaviour during casting.

The immediate difficulty is that there is no precise method of measuring the viscosity (fluidity is taken to mean the reciprocal of viscosity) or thixotropy since ceramic slips are generally anomalous and the apparent viscosity depends on the rate of shear. Certain simplified instruments such as the torsion viscometer give a rough and ready indication of the properties of the slip, but can under some circumstances be seriously misleading. It was therefore necessary to design an apparatus which would give much more precise information, in the hope that it would provide a two-fold benefit. It would enable the behaviour of various kinds of slips to be more adequately understood, and it would lead to the design of a better type of works instrument based on much more sound principles than had hitherto been possible. The essential factors of such an instrument are that it should enable the shearing stress to be quickly altered over wide ranges, and that it should register a corresponding change in the rate of shear almost instantaneously. This is necessary because the rate of build-up

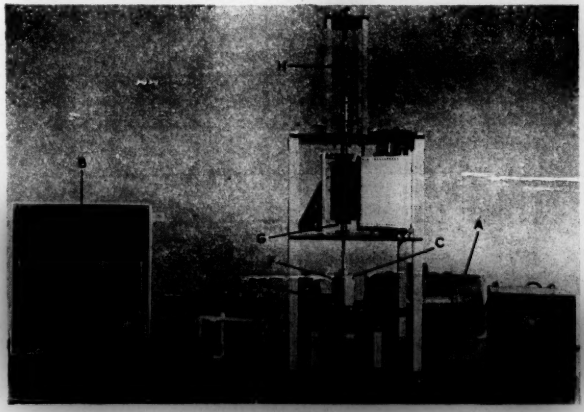

Fig. 2 — *Rotational viscometer.*

and break-down of thixotropic structures is extremely rapid. A concentric cylinder-type of apparatus was designed, using a narrow gap in order to maintain the shearing stress as constant as possible and using a special design in order to eliminate end effects. The apparatus is illustrated in Fig. 2. The material under examination is contained in the cup (F) which is driven by the variable speed motor (A) through the gears (E and D). The bob (C) is immersed in the material and is attached to the viscometer spindle (G) which carries part of the torque-recording system and is attached to the helical spring (H). Rotation of the cup tends to turn the bob with it until the torque transmitted by the material is just balanced by that due to twisting the spring. The speed of the motor is controlled by the electronic control equipment (B), and continuous control can be obtained over a speed range of twenty to one, the new speed being very quickly attained and being insensitive to changes in the load. The combination of gears E and D gives a variable range of speeds from 0·2 r.p.m. to over 400 r.p.m., corresponding to rates of shear varying from 0·18 to 360 reciprocal seconds. The torque transmitted to the viscometer bob is measured by the angle of deflection of the helical spring (H), which is recorded by means of a spark on a paper chart. A continuous record is thus obtained of the torque. Some typical results are shown in Figs. 3 and 4. In Fig. 3 a straight line for castor

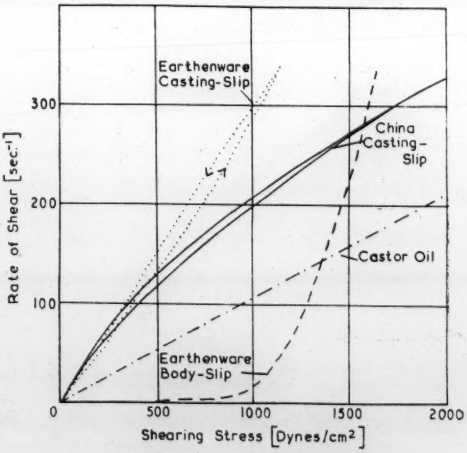

Fig. 3.—Consistency curves for ceramic materials.

oil represents the behaviour of a Newtonian liquid. The earthenware body slip provides a good example of simple plastic behaviour. Above a rate of shear of about 100 sec.$^{-1}$, the consistency curve approximates to Bingham behaviour with a straight line cutting the stress axis at about 1,200 dynes/cm.^{2} Below this the curve deviates markedly from Bingham behaviour and at about 500 dynes/cm.^{2} the actual yield point is much lower than the extrapolated value. The slip does not flow under its own weight, but can easily be stirred rapidly. When alkali is added to this slip we obtain an earthenware casting slip, the behaviour of which is also shown in Fig. 3. Two factors will be immediately noted. The yield point has been considerably reduced, and there is now a thixotropic loop. This means that higher fluidities can be obtained and that the thixotropy will help the material to set.

A china casting slip shown on the same diagram shows quite a different type of curve. Again there is no yield point, but now there is conspicuous dilatancy and also negative thixotropy.

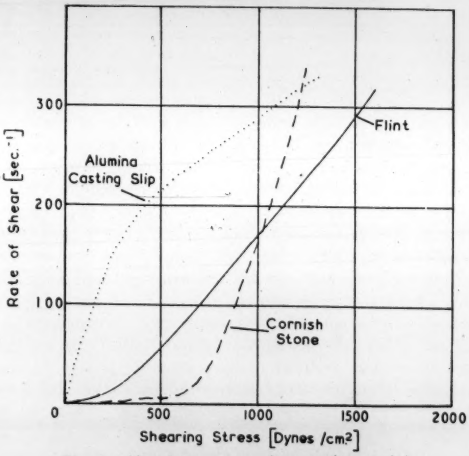

Fig. 4.—*Consistency curves for ceramic materials.*

In Fig. 4 consistency curves are shown for a number of slips containing no clay, which would therefore normally be regarded as inert in the rheological sense. The flint sample gave a curve which did not deviate very much from Newtonian behaviour, although it could be described as slightly pseudoplastic. A Cornish stone slip, on the other hand, which might be expected to behave very much in

the same way as flint, gave a curve which, except that it had very low rates of shear, was that of an ideal plastic. The alumina slip which was made from alumina particles of less than 5μ diameter and deflocculated with dilute acid gave a strongly dilatant type of curve. The flint and stone curves provide a good example of the limitations in industrial use of single-point measuring viscometers. Thus, an instrument designed to measure viscosity at a rate of shear of 100 sec.$^{-1}$ would indicate that the stone was the more viscous slip. The instrument operating at a shear rate of 300 sec.$^{-1}$ would find the flint the more viscous slip. Even greater confusion would arise in an instrument, such as the torsion viscometer, in which the shear rate was not constant but varied during the measurement. In this case a complex average value is obtained which is practically impossible to interpret. A comparison of the flow properties of slips is not possible unless measurements are made over a wide range of rates of shear.

(*c*) *Drying.*

One of the most difficult problems in the making of most kinds of ceramic products is the drying of the unfired article. The water has to be removed in such a way as to cause neither obvious rupture or distortion, nor hidden strain which may make itself felt later during the firing. The problem facing the physicist here is to find what conditions of temperature, humidity and air velocity make for rapid removal of water, without distortion or rupture of the piece.

Clay contracts on drying. It follows from this that where two parts of the same piece are at different moisture contents, the moisture gradient will be accompanied by stresses. Since clay in this state is readily deformable, distortion may occur, and since the tensile strength is low, cracking may also result. If temperature gradients are also present, thermal expansion effects will become apparent, and both these phenomena are of particular importance in the drying of very thick pieces. In the sanitary and heavy clay industries, thicknesses of four to six inches are very often encountered and the maintenance of uniformity in these circumstances is not easy.

Some help is immediately forthcoming if the mechanism of drying contraction is analysed in more detail. At high moisture contents there is a rapid initial shrinkage as the water is removed. At this stage all the particles are separated by a continuous body of water ; as the water is taken away the particles are able to move nearer together ; and there is an approximately linear relation between the change of size and the decrease in moisture content. At about 17 per cent in the example shown, there is a critical moisture content, below which the contraction becomes much less marked. It is considered that at this stage the particles are in contact, and removal of more water merely results in the draining of the interstitial

pores. Surface tension forces now become operative ; but as the amount of water becomes less and less, the surface tension forces diminish and thus allow the structure to expand slightly. The important point emerging from this analysis is that as soon as the critical moisture content for a particular body has been reached the size changes are much less marked and the risk of distortion or rupture is less serious. It is also clear, however, that drying conditions which result in one part of an article being above the critical condition and another below at the same time are likely to give rise to trouble.

The super-position of thermal stresses on the contraction stresses results in a very complex state of affairs and this has led to much attention being given to the possibility of so-called " humidity drying." In this technique the ware is first heated up in an atmosphere of high humidity so that no drying is allowed to take place. When uniformity of temperature has been attained, the humidity is reduced and drying commences. The thermal and moisture gradients are thus separated. It will not, however, be possible to take full advantage of this principle until much more is known about the vapour pressure characteristics of water present in porous bodies. This water does not behave in the same way as " free " water, and difficulties due to condensation effects are frequently met with.

The rate at which water can be removed from a body, as distinct from the strains which may result, is also in need of much more detailed study. So long as the pores are full, the rate is mainly governed by the rate of removal from the surface, and this is conditioned by the temperature, the humidity, and the speed and direction of the air flow. Below the critical moisture content the internal processes become important, and the drying rate tends to be controlled by the rate at which the water can be transferred to the surface from the interior. It is in this stage that the influence of such factors as surface tension, soluble salts, viscosity and pore size become of obvious importance in the flow of water through the capillaries. From all these points of view drying provides an outstanding example of the relevance of physical analysis to an industrial problem.

V — CERAMICS AND THE PHYSICIST

Physics is sometimes defined as the study of the nature of matter and energy, and the interaction between them. In ceramics, the matter is to be found in great abundance in the earth's crust. It is fashioned by the application of various kinds of force into shapes both of beauty and of utility, rendered permanent by heat, and finally expected to withstand all the shocks and strains to which it is subject in use. Its behaviour under the influence of all these manifestations of energy forms a complex pattern of phenomena in which every true physicist

should find himself very much at home. An increasing proportion of modern research in ceramics is concerned with the structure and physical properties of materials, and their behaviour under applied stresses of various kinds. There is great scope for the physicist who is interested in the bulk properties of matter and the structural features on which they depend. The problem is a difficult one in the sense that it requires a sound grasp of the concepts of atomic and crystal configurations, and above all the ability to adapt and apply them to ceramic materials. Here the crucial difficulty is encountered that ceramic materials, being in the main compounded from naturally occurring minerals, are essentially inhomogeneous and indefinite in composition, and frequently associated with impurities. Fired ceramic products are generally polymorphous ; amorphous, glassy and crystalline phases frequently exist together in the same material. The physicist is required to develop an interpretation of much experimental data concerning the changes which occur when clay is heated in conjunction with other materials, the relationship of clay to water in both plastic and fluid states, the factors which make for high strength, the electrical and thermal properties, the changes which fired materials undergo in use, and so on. Much of this is still unexplored ground, and should present a stimulating challenge to the young physicist, not particularly keen to be associated with nuclear physics and atomic energy, but wishing to undergo the discipline of trimming his textbook physics to fit the problem of real materials.

ACKNOWLEDGMENT

The author is indebted to Dr. A. T. Green, Director of Research, The British Ceramic Research Association, for permission to publish this article.

INDEX TO VOLUME 5

SUBJECTS

	PAGE
Accounts for 1953	86
Annual Conference of Branch and Group Officers	190
Annual General Meeting, 34th	53, 135
Applied physics—	
in the Graduateship Examination	159
The Teaching of	198
National Certificates in	196
Authors, Notes for	195
Bequest to the Institute	195
Birkbeck College, The physics department of	150
Board—	
Ballot for the	111
Chairman : North-Eastern Branch	208
Nominations to the	58
Officers and Members of the	194
Report of, for the year 1953	72
Books, Reviews of (*see* Reviews of books)	
British Ceramic Research Association	224
British Non-Ferrous Metals Research Association	41
Budget, The Institute's 1954	49
Conferences—	
Branch and Group Officers	190
Education Group	25
Electron Microscopy Group — report	189
Institute of Physics Conferences	10, 49
Luminescence	27, 162, 207
Particle Size Analysis	27, 207
Correspondence—	
(H. Steels)	176
(T. A. Littlefield)	188
Course of lectures on precision measurement	205
Cockcroft, Sir John	193
Crest, The Institute's	137
Education Group Conference	25
Electron Microscopy Group Conference	189
Electronic engineering industry, The physicist in the	117
Electronics Group : Cambridge Conference on Luminescence ...	27, 162, 207
Electronics Group visit	190
Examination, Graduateship (*see* Graduateship examination)	
Examination, National Certificates in Applied Physics	196
Exemption from the Graduateship examination	196
Expulsion of a Fellow	180
Finance, The Institute's	54
First year university physics courses	181
Gifts to the Institute, Presentation of	58, *facing* 204
Gifts for the Institute's House	136
Graduates, Inquiry into the occupations of	24

	PAGE
Graduateship examination—	
Exemption from the	196
General Education paper of the	205
Modifications to syllabuses	136
1954 examination	25, 174
1955 examination	205
Graduateship examination, Applied Physics in the	159
Graduateship, Transfer to	27
Honours List	24
Hospital physicist, The work of a	127
Institute's House, Gifts for the	136
Institute of Physics—	
Accounts for 1953	86
Annual Conference of Branch and Group Officers	190
Annual General Meeting, 34th	53, 135
Bequest to the	195
Budget, 1954	49
Conferences of the	10, 49
Crest of the	137
Finance	54
Gifts for the	136
Nominations to the Board of the	58
Notes on the early history and growth of the	145
Officers and Members of the Board, 1954-55	194
Presentation of gifts to the	58, *facing* 204
President, 1954–55	193
Institution of Electrical Engineers, Publications of	206
Inquiry into the occupations of graduates	24
Journal Supplements	207
List of Members	25, 137
Luminescence, Conference on	27, 162, 207
Members—	
List of	25, 137
News of	138, 188, 212
Molecular structure and spectroscopy, Symposium on	26
Museum objects, Physical methods in the care of	61
National Certificates in Applied Physics	196
Nominations to the Board	58
North-Eastern Branch : Chairman	208
Notes for Authors	195
Notes on the early history and growth of the Institute	145
Occupations of graduates, Inquiry into the	24
Officers and Members of the Board, 1954–55	194
Optics, The teaching of	97
Particle size analysis, Conference on	27, 207
Physical methods in the care of museum objects	61
Physical Society—	
Exhibition, The 1954	25
Meetings	71, 197
Summer Meeting, The	126
Physicist in the electronic engineering industry, The	117
Physics department of Birkbeck College, The	150
Physics in technical colleges ; Sir John Cass College, London	11
Precision measurement, Course of lectures on	205

PAGE

Proceedings of the 34th Annual General Meeting 135
Publications of the Institution of Electrical Engineers 206
Recognition of Technical Colleges, The 21
Reports of Branch and Group Meetings—
Education Group Summer Meeting 176
London and Home Counties Branch Summer Meeting 164
Manchester and District Branch Summer Meeting 177
Yorkshire Branch Conference : Summary of a discussion on the education of physicists 217
Yorkshire Branch Summer Meeting 164
Register 18, 34, 112, 141, 190, 213
Research Associations—
British Ceramic 224
British Non-Ferrous Metals 41
Wool Industries 2
Reviews of Books—
A concise history of mathematics 179
A laboratory manual of experiments in physics 108
Aesthetics and the Gestalt 28
An introduction to relaxation methods 96
An introduction to the mathematics of physics 210
Art of scientific investigation, The 30
Atomic energy : A survey 140
Atomic energy and its application 211
Circuit theory of electron devices 94
Electricity and magnetism 209
Electricity and magnetism for degree students 16
Electromagnetic fields in its engineering aspects, The 178
Fields and waves in modern radio 50
Introduction to typography 180
Into space 31
Nuclear physics 109
Mechanics of materials 31
Physics, principles and applications 110
Practical metrology 17
Properties of matter 139
Radioactivity and radioactive substances 29
Security and responsibility 95
Sound 28
Statistics for technologists 50
Textbook of physics 208
What happens in singing 51
Royal Society, Elections to the 58
Russian crystallographers, Message to 26
Scholarships abroad, 1954–55 26
Society for Visiting Scientists 208
Summer Meetings—
Education Group 176
London and Home Counties Branch 164
Manchester and District Branch... 177
Physical Society, The 126
Yorkshire Branch 164
Supplements, Journal 207

PAGE

Symposium on molecular structure and spectroscopy 26
Teaching of applied physics, The 198
Teaching of optics, The 97
Technical Colleges, Physics in ; Sir John Cass College, London 11
Technical Colleges, The Recognition of 21
Undergraduate physics 37
University physics courses, First year 181
Whipple, The late Mr. R. S. 1
Wool Industries Research Association 2
Young, Thomas 165

AUTHORS

Bailey, G. L. J., British Non-Ferrous Metals Research Association, The ... 41
Burnett, R. E., The Physicist in the electronic engineering industry ... 117
Cassie, A. B. D., The Wool Industries Research Association 2
Clarke, N., Notes on the early history and growth of the Institute ... 145
The recognition of Technical Colleges 21
De Barr, A. E., Applied Physics in the Graduateship Examination ... 159
Dinsdale, A., The British Ceramic Research Association ... ...
Furth, R., The physics department of Birkbeck College 150
Humphry, R. H., Physics in technical colleges, Sir John Cass College, London 11
Kuhn, H. G., The Teaching of Optics 102
Mendelssohn, K. A. G., First year university physics courses 181
Newton, J., The Teaching of Applied Physics 198
Oldham, F., Thomas Young 165
Rawlins, F. I. G., Physical methods in the care of museum objects ... 61
Selwyn, E. W. H., The Teaching of Optics 104
Stone, R., The Teaching of Optics 97
Tebble, R. S., Summary of a discussion on the education of physicists ... 217
Thomson, J., Undergraduate physics 37
Weintroub, S., First year university physics courses 185
Wood, R. G., The work of a hospital physicist 127

Physicist or **electrical engineer** required at **Ministry of Supply London H.Q.**, responsible for development of air photographic equipment. Duties include preparation of contract proposals for research and development projects, scrutiny of specifications, supervision of the work and assessment of results. Qualifications, first or second class honours degree or equivalent qualification in physics or electrical engineering. Research experience in physical optics, photo-electricity, photographic processes or electronics required. An aptitude for originating and supervising research and development projects desirable. Salary within range Senior Scientific Officer (minimum age 26) £975–£1,150.

Scientific Officer (minimum age 21) £470–£855. Women somewhat less. F.S.S.U. benefits may be available. Application forms from M.L.N.S., Technical & Scientific Register (K), 26 King Street, London, S.W.1., quoting A291/54A. Closing date 20 December, 1954.

Photoconductivity. In connexion with important commercial and services contract developments a vacancy exists for a **physicist** or **physical chemist** to lead a small team undertaking investigations into the properties and applications of photoconductive materials. Applicants must have had research experience, academic or industrial, in this or a closely allied field. The company concerned comprises the Vacuum Tube Division of the Pye Group and has the backing of the resources of the Group. Applications should contain the maximum amount of relevant information and should be addressed marked "Personal" to The Director, Cathodeon Ltd., Church Street, Cambridge.

"Shell" Refining and Marketing Co. Ltd., has vacancies at its **Stanlow Refinery** near **Chester** as follows :—1. For a **physicist** whose interest lies in the development or adaptation of special instruments for the continuous recording and controlling of the quality of petroleum products. An honours degree is essential and previous experience of instrumentation or process control is desirable. 2. For a **physicist** or **physical chemist** to work initially in a small team which analyses petroleum refinery difficulties or new processes and carries out experimental work of very diverse character. Training in all aspects of refinery operations will be given and there is opportunity for advancement in the many branches of refining. An honours degree is essential.

Salary in accordance with qualifications and experience. Contributory pension scheme. Applications should be addressed to :—"Shell" Refining and Marketing Co. Ltd., Personnel and I.R. Department, Shell Court, White Kennett Street, London, E.1.

A **physicist** with industrial experience of instrument development is required to join a small team engaged in the design and manufacture of special-purpose apparatus. The work is concerned with a wide variety of physical principles and manufacturing techniques. A man possessing a General Science degree, preferably including Chemistry and with practical experience of mechanical and electrical engineering would be suitable. The appointment is at the applicational research centre of a major oil company located near Chester. Starting salary according to age, qualifications and experience. Attractive pension benefits. Write giving full details experience, qualifications, age, marital status, to Box ZG.946, Deacon's Advertising, 36 Leadenhall Street, London, E.C.3.

British Rayon Research Association. The Association has a number of vacancies for **physicists** or **physical chemists** on the research staff. The work will involve both fundamental and applied research on textile fibres and related materials.

Applicants should have a good honours degree, preferably with some research experience, not necessarily in textiles. Applications, with full details and names of two referees, should be addressed to the Appointments Officer, British Rayon Research Association, Heald Green Laboratories, Wythenshawe, Manchester.

The British Northrop Loom Company Ltd., Blackburn. Opportunities are available in the expanding research and development department of this progressive textile machinery firm for young **engineering** and **physics graduates.** Previous employment on research is not essential, but candidates must have a good general engineering and scientific knowledge, and be prepared to apply this to unexplored projects under the supervision of the senior scientific staff. The posts offer excellent prospects with salary according to qualifications and experience, and a generous pension scheme. Apply, in the first instance, to the Secretary.

ASSISTANTS

Nelson Research Laboratories have vacancies for **assistants** in interesting work on the physics and development of magnetic and electrical insulating materials and devices. Graduates with or without industrial experience and people with national certificates in electrical engineering or physics are required. Apply to Department C.P.S., 336/7 Strand, London, W.C.2, quoting Ref. 928E.

Technical Assistant required for work on the development of testing of semi-conductor devices. The work will be of a varied nature and will require electrical knowledge and some mechanical aptitude. Candidates should possess a Higher National Certificate or a National Certificate in Applied Physics and should have completed or be exempt from National Service. Apply in writing, giving particulars of qualifications, experience to the **Staff Manager (Ref. RLP/412), Research Laboratories of The General Electric Co. Ltd., East Lane, North Wembley, Middx.**

Imperial Chemical Industries Limited, Billingham Division, has vacancies for **physicist** and **mechanical engineering male assistant technical officer** posts in their engineering research laboratories. Candidates should be not more than 27 years of age and should have an Inter-B.Sc., a pass degree or a Higher National Certificate qualification. Salary will depend on qualifications and experience but as an indication, candidates could expect to rise to a salary of £730, £850 or an even higher figure. Write, giving brief details of career to the Staff Manager, Imperial Chemical Industries Limited, Billingham Division, Co. Durham, quoting reference W.1.

Organization engaged on **metallurgical research** requires an **assistant** having Higher National Certificate in Applied Physics or equivalent, for its Metal Physics section. The successful applicant will assist in research investigations and in the construction and maintenance of electronic and other equipment used by the section. Application stating salary required to be sent to :—The Director of Research, Aluminium Laboratories Limited, Banbury, Oxon.

(*Continued on page iv*)

Engineers and physicist.—Ferranti Limited in their new laboratories are engaged in a programme of electronic development of great industrial importance. The work involves the use of digital computers to control machines and industrial processes, and covers a wide and expanding field of application, offering long-term interest to those engaged in it.

Development activity for these projects is taking place in the fields of electronic circuitry (including pulse technique), digital computers, magnetic recording and servo-mechanisms. Engineers and physicists having experience as well as interest in one or more of these subjects are invited to apply.

The appointments are permanent and offer full scope for initiative in an expanding organization. A salary commensurate with the qualifications required will be paid. Staff Pension Scheme. Application form will be sent on request (quoting Ref. EP/AL) to the Personnel Officer, Ferranti Limited, Ferry Road, Edinburgh, 5.

COURSE OF LECTURES

Borough Polytechnic
Borough Road, London, S.E.1.

A course of ten lectures on Nuclear Particle Techniques

will be given by members of the staff of the Atomic Energy Research Establishment and by physicists from the London Medical Schools, on Wednesday evenings at 7 p.m. The first lecture will be on 12th January, 1955. These lectures are designed for those who use Nuclear Particle Techniques and are concerned with their applications. The course fee is £2 10s. 0d. Further particulars and application forms can be obtained from the Secretary of the Borough Polytechnic.

J. MILNER & SONS LTD
PRINTERS
BRENTFORD MIDDLESEX